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LIGHTING DATA

EDISON LAMP WORKS
OF GENERAL ELECTRIC COMPANY

GENERAL SALES OFFICE HARRISON, N. J.

Illumination and Production

Information compiled by
R. E. HARRINGTON
Lighting Service Department

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SYNOPSIS: PAGE

For information regarding MAZDA lamps and lighting questions, refer to the nearest sales office as listed on the last page of this bulletin.

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FRANKLIN INSTITUTE
PHILADELPHIA

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Introductory

The question of correct and adequate artificial illumination is one which warrants careful consideration by plant managers. It is one form of expenditure which brings the greatest returns for the money invested. In spite of this fact, many plant managers have neglected this opportunity to increase the overall efficiency of their plants. This is evidenced by the many examples of factories that are not only inadequately illuminated with regard to the amount of light, but are improperly lighted from the standpoint of reflecting equipment and location of lamps.

That artificial illumination is a necessity is not open to argument. Just consider the utter chaos the industrial world would be thrown into, if it was suddenly deprived of artificial light. Many operations requiring continuity would stop, while general production would be very greatly curtailed. What this means with regard to our economic, social and political problems, can only be surmised. We must, then, have artificial light in some form or other.

Since this is so, a plant manager, in planning for operation must include, in his general scheme, a means of providing artificial illumination. This, of course, means an initial investment in material and work for the installation of the system. That it is a sound investment to plan a system that will give proper, as well as adequate, illumination will be shown later on. In plants already equipped, but poorly lighted, it will be found economical to discard the old system and install a modern one.

With a properly designed and installed lighting system, the following advantages are found, as contrasted with the conditions under a poor system: better health conditions; less labor turnover; greater activities; better workmanship; fewer accidents and decreased spoilage. All of these factors combined assist toward the desired end—increased production.

Health

No one needs to emphasize the absolute necessity of protecting the eyesight of the worker. If sufficient illumination is not provided, the eyes are continually subjected to a strain in their attempt to discern detail. This rapidly fatigues, lowers

the bodily efficiency and may produce permanent injury. Even with plenty of light, if brilliant light sources are permitted to be in the field of view, bad conditions exist.

Several states, recognizing the beneficial effects of illumination on the health and safety of employees, have adopted lighting codes. These stipulate the minimum intensities permissible for certain operations, and also indicate the desirable intensities. These codes also indicate the allowable equipment to be used in order to eliminate glare, etc.

Good lighting is also reflected in the faces of the operators, in the form of healthful, buoyant spirits. Bad lighting is irritating because it makes it difficult to see, and strain is involved in the efforts of workers to adapt themselves to unnatural conditions. The mind, unconsciously, perhaps, becomes obsessed with the idea that it is being imposed upon. Everyone has seen this condition evident in employees; possibly the reader himself has experienced this feeling of resentment. Bad lighting will react to produce nervous, irritable, discontented employees.

Any plant manager knows that the experienced or trained man is an asset not easily replaced. If this man has been working continuously under insufficient illumination, its detrimental effect will eventually show up in his failing eyesight. He becomes incapacitated at the very time when he should be yielding the biggest return on the investment made in training.

The general appearance of the plant is materially improved, on account of the cleanliness which of necessity results. Dirt and refuse will not be permitted to lodge everywhere, if it is revealed to the scrutinizing eye of the superintendent. Dark corners always tend to gather waste material.

The question of shop sanitation is one that is receiving ever increasing attention, for an employer fully realizes that a healthy operator is an asset to his plant. Proper illumination is one of the greatest helps in attaining this result.

Labor Turnover

It has been demonstrated with absolute certainty that everyone prefers a cheerful, clean, well-lighted room as a place to work. If a shop is well lighted, it will perforce be clean and will become a veritable magnet in attracting help. Cases are on record, where one mill in a section has been markedly better illuminated and has

actually, through this means, obtained the very pick of the hands in the surrounding country.

At one time, not so far distant, it was assumed by many employers that a continual changing of employees was the best means of keeping down labor cost. Today this is not true, as such a method disrupts the organization, increases mistakes and accidents and, in fact, lowers the entire efficiency of the plant.

This, then, is the changed viewpoint of the employer as regards labor turnover. Paralleling this change has been one of as great

FIG. 1

The illumination in this picker room in a Southern cotton mill is accomplished by means of 100-watt Edison MAZDA C lamps in bowl-shaped enamel steel reflectors. The white walls and ceiling, as well as the light-colored material, assist in making this a cheerful workroom. All parts of the room are excellently illuminated, moving parts are easily seen, and work may be carried on with maximum speed

importance in the case of the employees. They have been gradually taking a more active part in saying what their working conditions shall be. If these are not satisfactory, they will quit and go where conditions suit them. Shop committees are formed who place

their grievances, just or unjust, before their employer and, unless an adjustment is made, serious labor trouble is sure to follow.

Since adequate illumination has a very marked influence on many of the items which labor is vitally interested in, such as health, safety, etc., it is obvious to conclude that the well-lighted shop is one in which the labor turnover will be at a minimum, other things being equal.

Safety

A survey of the accident records of insurance companies show that the greatest number of accidents occur during the days of least natural light. These records also show that about 25 per cent of all the industrial accidents might have been avoided, if adequate illumination had been provided. In fact, insufficient illumination is frequently held by juries to be contributory negligence. These points are, in themselves, sufficient evidence of the relations between correct illumination and safety. For further material on the relation between illumination and safety, refer to Lighting Data, Index 18.

Spoilage

There is no doubt that spoilage and "seconds" are one of the greatest "bugbears" of the manufacturer. Spoilage means a direct loss, as there is no return on the investment in material, labor and overhead. "Seconds" are nearly as bad; for, while they have some redemption value, they represent as much investment as "firsts," but not as much selling value.

That correct and adequate illumination has a very marked effect on the question of spoilage, is recognized. The mechanic can more easily and accurately read his blueprints, micrometers and gauges. When working to thousandths of an inch, the reading of a micrometer a thousandth off, may mean the difference between a "first" and a "second."

This argument does not alone apply to the mechanic. The carpenter, the weaver, in fact, everybody will find it easier to work correctly under a good system of high intensity, than under many of the systems at present in use.

One of the aims of the plant superintendent is to keep down spoilage. Since correct illumination is one of the obvious means to this end, it is surprising that so little attention is paid to it. This, perhaps, may be due to the idea that lighting is expensive. That this is a fallacy will be shown later.

Production

As stated previously, all of the effects of adequate illumination just considered have a very marked influence on production. It is obvious that a sanitary plant in which the employees are contented, and where accidents and spoilage are at a minimum, must be one in which production is high. There are other reasons, also, why the well-lighted plant shows better production than the poorly lighted one.

Fig. 2

An Excellent Example of High Intensity Illumination. The four 200-watt bow frosted Edison Mazda C lamps for each of the 20 ft. bays produce an illumination of approximately 13 foot-candles. Contentment of employees is one of the results of this installation. The cleanliness of the factory is evidenced from the photograph.

It is axiomatic that, for a plant to operate at all, it is necessary to provide means of illumination. Natural lighting in modern plants is obtained by the use of large window areas, and care is taken in designing these windows, in order to secure the best natural lighting conditions. Why should not as much care be taken regarding the artificial lighting? The latter must be paid for, while the former is free.

What are some of the effects when the artificial lighting is inadequate? The employee has been accustomed to daylight intensities, and if, when the artificial system is turned on, the intensity is low in comparison, his movements must slow up. He must be more cautious, for he has not the confidence which comes with clear vision. If he cannot readily see the figures on his micrometer or gauge, he loses time checking his work.

If he drops a tool, or piece of work, and it falls into a dense

Fig. 3
High Intensity, Well Diffused Illumination is Essential Where Fine Work and Polished Surfaces are Encountered. In this machine Shop approximately 9 foot-candles are secured by the use of 300-watt Edison Mazda C lamps equipped with Reflecto-cap diffusers

shadow, a few moments must be spent in searching for it. If his artificial light is of a type which is under his control, considerable time may be spent in adjusting it to suit his whim. It is perfectly obvious that all these items combine to decrease production. Conversely, if the illumination is adequate, the workman proceeds at his normal speed, and one can scarcely notice the effect of the diminution of daylight.

In addition to these effects, it is known that, under high intensity illumination, the eye functions more rapidly and more accurately than under low intensities. In other words, the employees are able to perceive details more easily and correctly. This effect can be interestingly shown by means of a shutter arrangement similar to that found in cameras. A printed letter or figure should be placed back of, and close to, the shutter opening. When the shutter is operated, under low intensity illumination it is impossible to distinguish details of the letter. If high intensity illumination be substituted for the low, it will be found that the letter can be read with perfect ease.

It has been stated that the above mentioned points are theoretical, and that the cost of installing and operating a good system outweighs the saving of employees' time. That this is not true, is shown by the following table of annual costs. This table is based on the use of a 100-watt MAZDA lamp per operator per 100 square feet, and shows the very small saving in time required to offset the cost of operation. In the tabulation it is assumed that the lamp burns two hours per day, 300 days per year

Cost of lamp (list, subject to discount)	$1.10
Cost of enameled steel reflector (list, subject to discount)	2.50
Estimated cost of wiring per outlet	6.00
Total first cost	$9.60
Interest on investment at 6 per cent	0.58
Depreciation on reflector and wiring at $12\frac{1}{2}$ per cent	1.06
Power at 5 cents per kw-hr	3.00
Cleaning at 3 cents per cleaning, two per month	.72
Renewal of lamp $\frac{600}{1000} \times \$1.10$	.66
Total	$6.02

Wages for 8 hours per day, 300 days, at 70 cents per hour are $1680

Ratio of cost of lighting per man to wages $\frac{\$6.02}{1680} = 0.356$ of one per cent

These figures, which are based on assumed conditions less favorable than ordinarily found, show that if a workman saves three minutes time per day, due to correct lighting, the entire operating cost of the system is paid for. They do not take into account the much smaller differential between the cost of good and poor illumination. Surely any employee will lose much more time than this under an inadequate system of illumination, when it is necessary to go to an individual lighting unit to read his figures, or to adjust the lamp in order to see his work better.

On the basis of the total cost of production, this percentage becomes so small as to be almost negligible. Indeed, it is sur-

prising that the one factor having the greatest effect on production at minimum expense has, until recently, been neglected by the industrial world.

The arguments, so far advanced, have as their basis what has been considered, up to the present time, as adequate illumination for industrial plants. It is of interest to note, however, that what is considered at present as adequate illumination, is of much higher intensity than that deemed sufficient several years ago. This is due to several factors, such as the introduction of incandescent lamps of much higher efficiency, the higher cost of labor and materials, the demands of workmen for better illumination, the realization by employers of the beneficial effects of increased illumination, etc.

What, then, are the limiting foot-candle values for artificial illumination, and is there such a thing as too high intensities? There are no limiting foot-candle values for artificial illumination with regard to the ability to see, providing the lighting system is properly designed and so installed as to avoid glare, etc. That the eye is able to adapt itself to very high intensities is evidenced by the perfect ease with which an employee is able to work near a window during a sunshiny day. The intensity in this case might easily range from 500 to 1000 foot-candles.

Tests recently made in an industrial plant where local lamps were used, supplemented by low value general illumination, showed that the illumination at the working point in certain instances was as high as 900 foot-candles. The work in this case was extremely fine and, because of the excellent conditions available, no complaints of eyestrain were heard. Although this latter is not cited as an ideal condition, it does show that intensities are being used that are many times higher than are generally realized. This point comes down, then, not to a question of too much light, but the proper use of that light.

With regard to practical operating conditions, the amount of light to be used is influenced by economic conditions. That is, there is a point at which the cost of supplying higher intensities overweighs the results from increased production. What this point is, however, has not been determined. That we are far from it, on the basis of present day intensities, is evidenced by production tests made under increased illumination. That this relation of the amount of light, to the amount of production, is of the greatest

importance is shown by the general attitude of many plant managers. Tests made by the Commonwealth Edison Co., of Chicago, show what marked effects may be expected by the introduction of this so-called high intensity illumination.

The results of these tests are given in an article in the March 22, 1919, issue of the *Electrical Review*, entitled, "Four Conclusive Tests of Productive Value of Good Factory Lighting." The material is so excellent that any plant manager, superintendent, or foreman, will find it well worth his time to read and study it carefully. Below are given a few of the important points in this article. These tests were carried on in four different manufacturing operations.

Test No. 1

IRON PULLEY FINISHING SHOP

	Old Installation	New Installation
Size of lamps	60-watt	200-watt
Type of reflector	None or tine cone	Reflecto-cap
Average watts per sq. ft.	0.27	1.9
Average illumination	0.2	4.8

In this particular case the new installation used 7.02 times as much power as the old, yet the following quotation from the article shows most remarkable results in increased production:

"Allowing 20 hours per month of 50-cent labor for cleaning the units, taking into account the increased consumption of electricity at the particular rate which the customer earns in Chicago assigning at least a 7-year life to the units, and capitalizing the investment at 6 per cent, the total cost will approximate $105 per month, which is some 5½ per cent of the monthly payroll of the shop—from 20 per cent to 35 per cent increased production at a cost of 5½ per cent of the payroll."

Test No. 2

SOFT METAL BEARING MACHINE SHOP

	Old Installation	New Installation
Size of lamps	100-watt	200-watt
Type of reflectors	Deep bowl	Deep bow
Average watts per sq. ft.	1.0	2.0
Average illumination	4.6	12.7

In this shop the increased production under the higher intensity illumination ranged from 8 per cent to 27 per cent. The test was carried on for a month under the low intensity, and a month under the high. The following excerpt is of particular interest:

"It was the intention to repeat this cycle, returning to the lower intensity for the third month and finishing with the higher value during a fourth; but, after the second month's experience using the daylight level, the management refused to return to normal, feeling that their production was of considerable more importance than the satisfaction of the testing engineers' desire to secure entirely unbiased data."

The other two tests also serve as confirmatory evidence of the value of high intensity illumination. In the third case, the illumination was increased from 3 to 11.7 foot-candles. The test was conducted in a heavy steel machine shop and showed increases in production of from 6 per cent to 14 per cent, with a cost of 1.2 per cent of the payroll.

In the fourth case, in a carburetor assembling shop, the illumination was increased from 2.1 to 12.5 foot-candles and resulted in from 6.5 per cent to 18.6 per cent increase in production. In this instance the cost was 0.9 per cent of the payroll.

It hardly seems necessary to further enlarge on the relations between high intensity illumination and increased production. The above cited tests are conclusive evidence. While the increased cost of the new system is given in terms of labor cost, it should be remembered that these figures, on the basis of the total cost of production, will be very decidedly less. In fact, with increases in production noted above, the additional cost due to higher illumination hardly warrants consideration. Paralleling this increased production, it is found that high intensity illumination results in better health conditions, less labor turnover, fewer accidents and less spoilage.

Design of Installation

Nothing has been said regarding the methods to follow in designing the lighting installation. This subject is of such importance, and covers so wide a field, that it has seemed desirable to treat it in a separate bulletin. Complete data on this subject will be found in Bulletin Index 13.

Fig. 4

The Drafting Room Requires Excellent Illumination. There must be good diffusion in order to eliminate misleading shadows from triangles and T-squares. The intensity must be high, so as to make easy the reading of fine lines. These conditions may be met by the use of the semi- or totally indirect systems of illumination. When these systems are correctly designed and installed, there is no necessity for locating tables with reference to lighting units, that is, tables may be located at any convenient point in the room with assurance of satisfactory illumination.

Bibliography

The following list indicates some of the leading articles on the general question of illumination and production and kindred subjects which have appeared in the technical magazines during the past few years:

"Effective Application of Productive Lighting," H. H. Magdsick, *Electrical World*, June 15, 1918

"Production Intensities," W. A. Durgin, Transactions Illuminating Engineering Society, Vol. 13, No. 8.

"Four Conclusive Tests of Productive Value of Good Factory Lighting," *Electrical Review*, March 22, 1919

"What Better Industrial Lighting Can Do to Stimulate Production," *Electrical Review*, September 6, 1919

"How Better Industrial Lighting Can Improve Working Conditions," *Electrical Review*, Septeber 20, 1919

"Possibilities of Industrial Lighting," R. O. Eastman, *Electrical World*, January 31, 1920

"Improving Shop Efficiency by Better Lighting," *Safety Engineer*, August, 1919.

"Factory Lighting for Safety and Production," E. A Anderson, *Safety Engineer*, August, 1919

"Economic Aspects of Industrial Lighting," C. E. Clewell, *Electrical World*, February 22, 1919.

"Shop Lighting for Production and Safety," W. A D. Evans, *Railway Electrical Engineer*, May, 1918

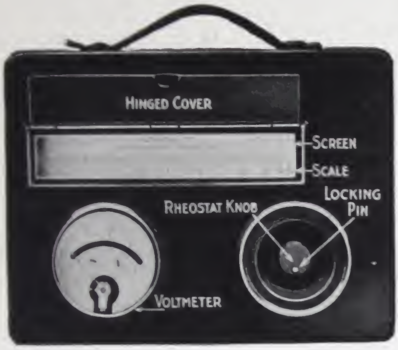
"Relation of Lighting to Industrial Safety," J. A. Hoeveler, *Electrical Review*, September 1, 1917

"Light and Output," A. S Turner, *Central Station*, November, 1917.

"Factory Lighting and Its Bearing on the Safety, Health and Productivity of Workers," L B Marks, *Safety*, January, 1917

Foot-candle Meter

In order for the plant manager to determine the intensities throughout his plant, it is desirable to have available an instrument, by means of which this may be done easily and quickly. The Foot-candle Meter meets these requirements. This instrument is self-contained and portable. Because of its small size, (7⅞ in by 6 in. by 1½ in.), it may easily be used to make illumination readings at any desired point. The instrument is calibrated before being shipped and, by means of the rheostat and voltmeter, which are a part of the instrument, it is possible to read intensities varying from 0.1 to 40 foot-candles. Although it is not quite as accurate as a laboratory instrument, it is sufficiently accurate to be of real practical value. At least one Foot-candle Meter should be a part of the equipment of every industrial plant.



By means of this instrument, a check may be kept on the lighting conditions in the plant. The manager or superintendent may easily determine whether or not the illumination for any given operation is comparable with what is considered sufficient for that operation. Complaints of various workmen regarding inequalities in illumination are readily settled, for the Foot-candle Meter will show the results secured.

Technical training is not necessary to the successful operation of the instrument. With a little experience anyone may read the resulting illumination. All that is necessary is to operate the rheostat until the pointer on the voltmeter comes to the indicated position. The Foot-candle Meter is then placed at the desired location and the illumination read by balancing the light and dark spots on the face of the instrument.

EDISON LAMP WORKS
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GENERAL ELECTRIC COMPANY
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*For Texas, Oklahoma and Arizona business refer to
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*Stock of lamps at these points

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